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# The potential for perimarine wetlands as an ecohydrological and phytotechnological management tool in the Guadiana estuary, Portugal

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**Abstract**

Climate and human impact on terrestrial sediment flux, nutrient and pollutant delivery to the coastal zone in the Algarve can be clearly demonstrated with both past and recent examples. A Holocene period of high sediment input, supporting a depositional coastal response to relative sea-level rise, has now given way to a period of coastal retreat where increased damming of rivers has led to reduced river flow and terrestrial sediment input. These changes in water and sediment budget are coupled with increased nutrient and pollutant influx associated with agriculture and industrial/urban development. Solutions to these problems may only be addressed through integrated river basin management, and with ecohydrological principles playing a critical role in the development and routine use of sustainable management techniques. Whilst riparian wetlands and saltmarshes are recognised as ecohydrological management tools with which to regulate hydrology, sedimentation, nutrient status and pollutant sequestration and the conservation of biodiversity, the same is not true of perimarine wetlands that occupy the transition zone between catchment and sea. Evidence from Holocene examples of estuarine and back-barrier perimarine wetlands in the UK suggests that they are well adjusted to the conditions of high relative sea-level rise ($3-6\ \mathrm{mm\ yr^{-1}}$) and low terrestrial sediment supply. Whilst Holocene examples in Portugal are sparse, the present conditions of reduced sediment input due to damming and enhanced relative sea-level rise due to Greenhouse warming now makes perimarine wetlands a viable coastal management option. Here, the benefits and practical aspects of perimarine wetland development are considered with a view to establishing a demonstration pilot project in the Guadiana.


*Keywords:* ecohydrology; phytotechnology; river basin management; coastal change; sediment; nutrients; pollutants

## 1. Introduction

### 1.1. Integrated river basin management and estuarine ecohydrology

Ecohydrological principles address the interaction between catchment hydrology and biota through considering the drainage basin and, where appropriate, its contiguous estuary as a single ecological entity or 'super-organism'. From a management perspective, the capacity of this uplands-to-seas super-organism to cope with stresses resulting from human activities, as well as external stressors such as climate change, can be enhanced by using the biota to regulate hydrologically-driven processes such as flooding, sediment flux, nutrient and pollutant transfer (*cf.* Zalewski, 2002; Wolanski et al., 2004). In the short-term, the focus of estuarine ecohydrology as a management tool is to provide low cost, holistic, sustainable solutions to human impact on the environment.

Ecohydrologically, the estuary is the end-member of the river where incremental small-scale impacts on various sub-units of a river catchment are made cumulative, and where the summation of minor environmental stresses may become critical. Significantly, addressing climate and human impacts on terrestrially-derived sediment, nutrient and pollutant flux to the coast is not just of importance in understanding the

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drivers of coastal sedimentation and evolution, but of central relevance to recent directions in integrated river basin management. In this context, UNEP have advocated an integrated approach to the hydrological environment, stressing the linkage between river and coastal systems (Coccossis et al., 1999; Burt, 2003). Similarly, this holistic, basin-wide approach is of central importance in the EU Water Framework Directive (EU-WFD), which is regarded as one of Europe's most ambitious pieces of environmental legislation to date. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, the EU Water Framework Directive (EU-WFD), was set up to establish a framework for community action in the field of European water policy. The increasing demand by citizens and environmental organizations for cleaner rivers, estuaries and lakes, groundwater and coastal beaches was regarded as one of the main reasons why the Commission has made water protection one of the priorities of its work. One element of specific relevance within the Directive to the issue of establishing the ecohydrology concept is that of a single system of water management: river basin management.

In addition to the general ethos and underlying principles of integrated sustainable development within the drainage basin and estuary, managers require techniques with which to tackle problems or maintain environmental quality. In the past, such techniques have focused on engineering and/or technological solutions, but often at the expense of catchment ecology and landscape aesthetics (for examples, *cf.* Jones, 1997); as well as at considerable expense. In this paper, we consider the potential of perimarine wetlands as a sustainable, low cost and low maintenance ecohydrological tool with which to manage sediment, water and pollution flux to and within the coastal zone. The value of such a perimarine 'buffer zone' is considered with particular reference to the UNESCO demonstration site for estuarine ecohydrology: the Guadiana river, where the potential for wetland development within the river corridor is limited.

## 2. Climate and human impact on sediment, nutrient and pollutant flux to the Algarve coast during the Late Pleistocene and Holocene

Human impact on landscape has increased the flux of sediment, as well as associated nutrients and pollutants, to the coast, perhaps since Mesolithic/Neolithic times, but certainly from the Bronze/Iron/Roman ages and especially since the Industrial Revolution. When coupled with tectonic setting, highly erodible catchment lithologies and soils, and dissection by dense drainage networks, it becomes readily apparent why significant climate and human impacts during the Late Pleistocene and Holocene have left an imprint on the Algarve landscape. In terms of landscape instability, the Algarve is probably more sensitive to these impacts than many parts of the circum-Mediterranean region (Chester and James, 1999). For example, Portugal possesses 93% of land with potential erosion risk and 84% of land with actual erosion risk (CEC, 1992). Significantly, Loureiro and Coutinho (1995) have shown the potential for rainfall to alter the balance between alluviation and incision, whilst Devereux (1983) links such an increase in erosivity to river valley bottom and floodplain deposition and lateral erosion.

Whilst it may be argued that climate change contributes to enhanced erosion, it was the impact of people on the landscape that was decisive during the late Holocene (Chester and James, 1999). For example, between *ca.* 40,000–35,000 and *ca.* 7400 years BP an extensive alluvial fill was deposited in the valleys of the Algarve primarily under the influence of cold, dry climatic conditions with episodic intense rain storms (Chester and James, 1999). van der Knapp and van Leeuwen (1995) also identify a climatic deterioration at *ca.* 8700–5670 years BP in the pollen record from Serra de Estrela in east-central Portugal. Here, human impact on vegetation becomes apparent from *ca.* 5670 to *ca.* 3220 years BP, with some evidence of grazing and small-scale local deforestation. Local over-grazing with soil erosion starts about 4550 years BP, with large-scale deforestation and the development of a cultural landscape characterising the period *ca.* 3220–955 years BP. The increase in the human influence on vegetation increases into the period of *ca.* 955 years BP to the present, to such an extent that the forests virtually disappear and organic soils are eroded.

Chester and James (1999) also suggest that two periods of rapid erosion characterise the last 3000 years in the Algarve. For the earlier period of hillslope erosion from 3000 to 300 years BP, valley floor deposition and estuary siltation are considered to relate to pre-Roman, Roman, Moorish and early Portuguese phases of settlement and clearance for agriculture and forestry. Following a period of reduced sediment delivery between *ca.* 1700 and *ca.* 1914, the 20th century witnessed renewed pressure due to a campaign for agricultural self-sufficiency, (e.g. wheat cultivation, and widespread ploughing and afforestation using *Eucalyptus globus*). Indeed, recent changes in agricultural policy have transformed the undulating 'Serra' regions, (i.e. the Alcoutim and Castro Marim regions of the Guadiana basin), leaving steep slopes and extremely poor soils exposed to erosion and susceptible to fire. An agricultural system of subsistence farming based on marginal cereal crops, sheep and goats has been replaced by intensive farming in which the increased surface area given over to cultivation and the removal of hedgerows has accelerated soil erosion and enhanced the eutrophication of rivers and ditches. This is particularly true of the 'corn campaigns' of the turn of the last century and of the 1930s, producing a homogenous *Cistus* scrubland cover with commercial plantations of *Pinus pinea* (Umbrella pines) with sparse *Prunus dulcis* (Almonds) and *Quercus ilex* (Holm Oak).

At the coast, the Holocene has been a period of estuary and back-barrier infilling and considerable shoreline change. Dias et al. (2000) note that the principal factor in shaping the Portuguese shoreline until the mid-Holocene was relative sea-level rise. In the Guadiana, Morales (1997) and Boski et al. (2002) recognise a period of estuary infilling between about 10,000 and 3000 years BP. This reflects a regional pattern of coastal change for the Gulf of Cadiz in which Holocene relative sea-level rise restricted sediment deposition to coastal embayments and estuaries (Borja et al., 1999). As a shallow coastal shelf developed, coupled with an attenuation of the